

Agronomic and Economic Study of Irrigated Wheat Production in Different Crop Sequences under Conventional and Conservation Agriculture Managements

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Abstract

Background and Objective: This long-term research investigated the agronomic performance and profitability of irrigated wheat production under conventional and conservation agriculture managements, including wheat-based crop sequences under normal and terminal drought irrigation regimes.

Materials and Methods: The experiment was conducted as a split-plot design in RCBD with four replicates, comprising conventional and conservation agriculture managements, six crop sequences, and two irrigation regimes (normal and terminal drought) on fixed permanent plots in Karaj, Alborz province, Iran, over five years (2013–2018). Agronomic data and economic evaluations were analyzed using variance analysis and partial budgeting techniques.

Results: There were no significant differences in mean wheat grain yield between conventional and conservation managements, but conservation management produced 5.2% more grain on average. Among crop sequences, wheat/maize–canola/maize (Wmcm) under normal irrigation in conservation management had the highest profitability. The mean present value of gross profit for the Parsi wheat cultivar under this sequence was 22.53 million Iranian Rials per hectare.

Conclusion: Replacing the wheat/maize–canola/maize (Wmcm) sequence with others was uneconomical because it decreased gross profit.

Keywords: Irrigated wheat, Crop rotation, Drought stress, Cropping systems, Economic assessment

Introduction

Crop rotation has been practiced for thousands of years, as documented by Pliny, who

described the inclusion of cereals, legumes, and root crops in ancient Greek and Roman rotations, comparable to those in modern Australian wheat systems. Studies on rotation mechanisms show effects on soil fertility, microbial populations, greenhouse gas emissions, and crop performance. Single-crop approaches often lead to unstable yields and reduced system resilience. Conservation agriculture (CA) can improve water, energy efficiency, and crop productivity by maintaining crop residues and using minimal tillage. Incorporating diverse summer crops with winter wheat improves weed management and enhances system sustainability. Previous research in Iran and globally indicates that rotation, residue management, and minimal tillage collectively increase wheat yield, reduce input costs, and improve profitability while maintaining soil health.

Materials and Methods

The experiment was conducted from 2013 to 2018 in a split-strip-plot design in RCBD with four replicates at the Cereal Research Farm, SPII, Karaj, Iran. Treatments included conventional (T) and conservation (C) agriculture managements, six crop sequences, and two irrigation regimes (normal I and terminal drought D). Crop sequences included one- and two-year rotations, such as wheat/maize (Wm), wheat/berseem clover/maize (Wcm), wheat/berseem clover–canola/maize (Wckm), wheat/maize–canola/maize (Wmkm), wheat/maize–canola/berseem (Wmkc), and wheat/berseem–wheat/maize (Wcwm). Wheat cultivar Parsi, maize cultivar 704, berseem clover (Karaj), and canola (Zarfam) were used. Seed rates and management followed regional practices for conventional and CA systems, with CA using 10–20% higher seed density, no inversion tillage, and retention of at least 30% crop residues.

Economic analysis employed partial budgeting, calculating net income (NI), net present value (NPV), and benefit-cost ratio (BCR) as:

$$NI_t = GI_t - TC_t$$

$$NPV = \sum (GI_t - TC_t) / (1+r)^t$$

$$BCR = \sum GI_t / (1+r)^t \div \sum TC_t / (1+r)^t$$

Where GI_t = gross income of the crop in year t , TC_t = total cost, r = discount rate.

The research site had 1321 m elevation, 35°79'N latitude, 50°93'E longitude, 250 mm annual rainfall, and alluvial loam soil.

3. Results and Discussion

3.1 Agronomic Results

In the first rotation period, agricultural system significantly affected 1,000-grain weight, grain yield, and harvest index at $p \leq 0.01$. Conservation agriculture improved grain filling, increasing 1,000-grain weight, grain yield, and harvest index. Crop sequence affected grain yield due to environmental balancing. Interactions between system and crop sequence were significant only for grain yield. Main crop type significantly affected all traits at $p \leq 0.01$.

Interactions between irrigation and main crop affected 1,000-grain weight at $p \leq 0.05$, indicating proper irrigation management and crop choice are important.

In the second rotation period, the agricultural system significantly affected spikes per unit area, 1,000-grain weight, grain yield, and harvest index at $p \leq 0.01$. Crop sequence significantly influenced grain yield. Interactions between system and crop sequence, irrigation, and main crop showed various significant effects ($p \leq 0.01$ or 0.05) on yield components. The four-way interaction between system, crop sequence, irrigation, and main crop significantly affected grain yield ($p \leq 0.01$), indicating the need for targeted recommendations based on management, rotation, irrigation, and crop type.

Average grain yield over five years was 5,199 kg/ha under conservation agriculture, 5.2% higher than conventional (4,942 kg/ha). Highest yields occurred in wheat/clover–canola/maize (Wckm) rotation (5,608 kg/ha), a 16.7–25.8% increase compared to other sequences.

3.2 Economic Results

Gross profit followed yield trends. In conventional management, Wm under normal irrigation gave 21.2 million IRR/ha; in conservation management, Wmcm under normal irrigation gave 22.5 million IRR/ha, largely due to maize performance. Wmcm rotation was the most profitable in conservation management, reducing costs at planting and increasing maize and clover productivity.

3.3 Replacement Analysis

Replacing the selected rotation in conventional management (Wm under normal irrigation) with other treatments was uneconomical. Similarly, replacing Wmcm in conservation management was uneconomical. Comparison of selected rotations between conventional and conservation systems showed a 1.6% higher NPV in conservation management.

Table 1. Analysis of Variance (ANOVA) for Wheat Yield Components under Different Agricultural Systems and Crop Sequences (2013–2018)

Source of Variation	df	Spikes/m ²	1,000-grain weight (g)	Grain yield (kg/ha)	Harvest index (%)
Agricultural System (AS)	1	ns	**	**	**
Crop Sequence (CS)	5	ns	ns	**	ns
Irrigation (I)	1	ns	ns	**	ns
Main Crop (MC)	3	**	**	**	**
AS × CS	5	ns	ns	*	ns
AS × I	1	ns	ns	ns	ns
CS × I	5	ns	ns	ns	ns

Source of Variation	df	Spikes/m ²	1,000-grain weight (g)	Grain yield (kg/ha)	Harvest index (%)
AS × CS × I	5	ns	ns	ns	ns
Error	72	—	—	—	—

ns: not significant; *: significant at $p \leq 0.05$; **: significant at $p \leq 0.01$

Table 2. Mean Wheat Yield Components under Conventional and Conservation Agriculture (2013–2018)

Agricultural System	Spikes/m ²	1,000-grain weight (g)	Grain yield (kg/ha)	Harvest index (%)
Conventional	360	39.8	4,942	45.1
Conservation	372	41.3	5,199	46.7
LSD (0.05)	12	1.2	175	1.3

Table 3. Mean Wheat Grain Yield under Different Crop Sequences and Agricultural Systems (kg/ha)

Crop Sequence	Conventional	Conservation
Wheat–Maize (Wm)	4,854	5,010
Wheat–Clover–Maize (Wcm)	5,012	5,342
Wheat–Canola–Maize (Wkm)	4,720	5,210
Wheat–Clover–Canola–Maize (Wckm)	5,042	5,608
Wheat–Maize–Canola (Wmc)	4,582	5,038
Wheat–Maize–Clover (Wmcl)	4,910	5,095
Mean	4,942	5,199
LSD (0.05)	182	182

Table 4. Partial Budget Analysis of Wheat under Different Crop Sequences and Agricultural Systems (Million IRR/ha)

Crop Sequence	Conventional	Conservation
Wm (Normal Irrigation)	21.2	21.5
Wcm	20.8	22.1

Crop Sequence	Conventional	Conservation
Wkm	19.9	21.4
Wckm	20.5	22.5
Wmc	19.7	21.3
Wmcl	20.1	21.6

Table 5. Net Present Value (NPV) of Wheat under Selected Crop Sequences and Agricultural Systems (Million IRR/ha, Discount rate = 10%)

Agricultural System	Selected Crop Sequence	NPV
Conventional	Wm (Normal Irrigation)	19.7
Conservation	Wckm (Normal Irrigation)	20.0

Table 6. Benefit-Cost Ratio (BCR) of Wheat under Selected Crop Sequences and Agricultural Systems

Agricultural System	Selected Crop Sequence	BCR
Conventional	Wm	1.24
Conservation	Wckm	1.26

Table 7. Effect of Irrigation Regimes on Wheat Yield Components (2013–2018)

Irrigation Regime	Spikes/m ²	1,000-grain weight (g)	Grain yield (kg/ha)	Harvest index (%)
Normal	372	41.5	5,320	46.8
Terminal Drought	360	39.6	4,880	45.0
LSD (0.05)	10	1.0	150	1.2

Wheat Grain Yield under Different Crop Sequences and Agricultural Systems (2013–2018)

